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A study of response latency in a drill-and-practice task showed that variability in latency measures could be reduced by the use of self-pacing procedures, but not by the detailed analysis of latency into separate components. Experiments carried out on instructional history variables in teaching a mirror image, oblique line discrimination, showed that the most successful procedures were to present the stimulus successively rather than simultaneously with short inter-trial intervals. In evaluating a computer assisted laboratory in statistical inference, it was found that positive attitudinal shifts toward computers resulted from working on a computer terminal. SKOOLBOL-I, a programing language used in psychological experimentation, was evaluated and modified, and basic design work on a second generation language was initiated. An analysis was compled of instructional strategies in terms of automata theory and linguistic models. Plans for the 1969 ONR-LRDC conference on "The Nature of Reinforcement" were completed. Several general papers concerned with concept learning, learning in relation to instructional research, and psychological questions in computer assisted instruction were published. A bibliography is appended. (JY)

STUDIES RELATED TO COMPUTER-ASSISTED INSTRUCTION

Semi-Annual Progress Report on Contract Nonr-624(18)

October 1, 1968 through March 31, 1969

Personnel and Training Branch

Psychological Sciences Division

Office of Naval Research

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CONTENTS

ABSTRACT

The parameters and concomitants of response latency in a drill and practice task were investigated. It was found that variability in latency measures could be reduced by the use of self-pacing procedures. Detailed analysis of latency into separate components did not decrease the variability of latency measures. Preliminary results on the relationship between response latencies during overlearning and subsequent retention showed a tendency for well-retained items to have shorter latencies than those poorly retained.

A series of experiments was carried out investigating instructional history variables in teaching a difficult, mirror-image, oblique line discrimination. Various techniques of stimulus fading and different feedback conditions indicated that appropriate stimulus control was difficult to obtain. Increased success was obtained when training procedures were changed from simultaneous to successive stimulus presentations, and when the inter-trial interval was decreased.

A computer-assisted laboratory in statistical inference was evaluated to determine its effect on mastery of statistical concepts and on attitudes toward the computer. It was found that exercises on the analysis of stored real data were more instructive and more interesting than Monte Carlo experiments. In general, working on a computer terminal was reflected by positive attitudinal shifts toward computers.

A preliminary programming language (SKOOLBOL-I) used for carrying out psychological experimentation on a PDP-7/9 time-sharing system was evaluated and modified. Basic design work on a second-generation, more general-purpose language was initiated for experimental work in computer-assisted instruction and the psychological laboratory. In a separate project an analysis was completed of different instructional strategies in terms of automata theory and linguistic models.

Plans were completed for the 1969 ONR-LRDC conference on the application of scientific developments to instructional technology. The conference topic this year is "The Nature of Reinforcement." Several general papers were published concerned with concept learning and concept teaching, a review of learning in relation to instructional research, and psychological questions in the development of computer-assisted instruction.

I. RESPONSE HISTORY VARIABLES RELEVANT TO INSTRUCTIONAL DECISION-MAKING

A. RESPONSE LATENCY (R. GLASER; W. A. JUDD)

1. Concomitants of Variability in Measures of Response Latency.

A series of parametric studies was completed which investigated experimental techniques for reducing the high degree of variability obtained in response latency measures. Two dimensions of control, both pertaining to paired-associate learning (drill and practice) tasks, were investigated:

Pacing. Previous work in this laboratory had paced the test phase of study-test paradigms by presenting the subsequent stimulus one and one-half seconds after the subject's previous response. Under these conditions, the subject was instructed to return his finger to a "home" position in the center of the key array following each response. In more recent work, it was reasoned that the variability might be reduced if the stimulus were presented at the subject's command rather than at a fixed interval. Consequently, a key was placed at the home position, and the stimulus was displayed when the subject pressed this home key. This provided the dual advantage of allowing the subject to control the inter-item interval and of assuring the experimenter that the subject's finger was in the home position when the stimulus was presented.

Decision latency vs. travel time. It is a common procedure in the study of reaction times to measure the latency of the initiation of the subject's response rather than the latency of the completion of the response. It was hypothesized that, given appropriate instructions and training, the total stimulus-response latency could be divided into two portions: (a) a decision period during which the subject decided which response he was going to make but

did not make any overt response, and (b) a travel period during which the subject made his actual response by lifting his finger from the home key and pressing one of the response keys. It was anticipated that the travel period would remain relatively constant during learning but would account for a considerable portion of the undesirable variability in the data. The home key was modified so that the time at which it was released could be detected. Subjects were given instructions appropriate to separating the decision and travel periods and during a pre-experimental training task, time limits were placed on each portion of the response. That is, the subject was allowed two and one-half seconds from the time the home key was pressed until it was released and one second from the time of release until the time of response completion. The time limits were not employed during the experimental task but the subjects were not informed of this change.

The first of the two studies run uncovered a flaw in the procedure of splitting the response into decision and travel periods. The response shaping employed in the pre-experimental task was apparently too successful. While the variability of the decision latency measure was substantially less than the variability of the total response completion latency, all responses, throughout the learning task, were quite fast. During the pre-experimental task, there were two opportunities for the subject to be punished for responding too slowly--during the decision period and during the travel period. As a result, the subjects learned to respond very quickly and maintained this behavior throughout the experimental task, effectively masking a substantial portion of the usual reduction in latency that occurs as a function of overlearning drill.

A second study altered the pre-experimental shaping procedure by allowing only three-quarters of a second for the travel period and placing no restraints on the length of the decision period. The self-pacing procedure was also used in this experiment. The usual reduction in latency as a function of overlearning was re-established

under these conditions. It was concluded that the variability of the latency measures was reduced by the use of the self-pacing procedure. The hypothesis that decision latencies would be less variable than the total S-R latencies was not confirmed. The standard deviations of the decision latency measures tended to be as large as or larger than the standard deviations of the total S-R latencies. In addition, there was a tendency for travel time to decrease as a function of learning rather than remaining constant as had been anticipated. Finally, it was concluded that the procedure of limiting response times during the pre-experimental training task, a procedure which had been used in all the previous latency work, was relatively ineffective in reducing variability.

2. Response Latency and Retention.

Current work consists of examining response latencies during overlearning of a paired-associate task with respect to the subsequent retention of individual items. This study has presented some problems of experimental control since the experimental questions concern differences between items as well as individual differences among subjects. It has been necessary that each item under consideration be given the same amount of overlearning drill. In order to accomplish this, items are dropped from the list as they are learned. The subject is presented with a list of 16 items. As each item reaches a predetermined item criterion, it is dropped from the list. When ten items have been dropped, training is terminated. The subject is then presented with the same list after an interval of several days, at which time retention and relearning measures are obtained. Preliminary results indicate that there is a tendency for well retained items to have shorter latencies during overlearning than do poorly retained items.

In the immediate future, research in the area of response latency will attempt to substantiate the preliminary finding of

of latency differences between well and poorly retained paired-associate items. Once the relationship is established, a limited number of parametric variables will be investigated in an attempt to define the extent of the phenomenon. Subsequent work will (a) attempt to define a relationship between response latencies and confidence ratings elicited from the subjects and (b) investigate response latencies in the context of concept formation tasks.

3. Technical Reports.

Within the next six months, several technical reports will be issued concerning the findings of this research: a revision of the earlier work (Judd, 1968) is scheduled for September, 1969 publication as a Monograph Supplement to the Journal of Educational Psychology; and technical reports will be prepared on the variability pilot work and the retention study described above.

B. INSTRUCTIONAL HISTORY VARIABLES IN DISCRIMINATION LEARNING.

(R. GLASER; A. SIEGEL)

In 1957, Sutherland reported a study in which an attempt was made to teach several discriminations to octopi. It was found that although a vertical-horizontal line discrimination was readily learned by these animals, a discrimination between two mirror-image oblique lines (45 and 135 degrees) was not learned. The initial explanation of these results was couched in physiological terms: It was postulated that the structure of the visual system of the octopus contained two kinds of stimulus analysers, vertical and horizontal. Thus, since oblique lines have equal amounts of visual and horizontal components, the analysers ought not be able to discriminate between them. In 1963, Rudel and Teuber performed a similar study using 4-year-old children. The results obtained paralled those of Sutherland in that it was found that a vertical-horizontal discrimination was

learned easily by these children, but a discrimination between two mirror-image oblique lines was impossible for children of this age. The method of stimulus presentation used was the classical two-choice simultaneous presentation, and reinforcement consisted merely of the words "right" and "wrong" contingent upon the nature of the child's choice.

In the context of an analysis of instructional strategies, the rationale behind the project began with the questions: why is this particular discrimination so difficult to learn, and how could the instructional situation be designed so that this supposedly impossible discrimination could be taught? The implications of work on this simple task could then be generalized to more complex learning. Earlier work (Cohen, et al., 1968) in the project on teaching a vertical-horizontal discrimination to children provided a starting point for current work. The study employed principles derived from previous experiments carried out by Terrace (1963) and Kish (1966). The study by Cohen and others (1968) incorporated two procedures which looked promising for further study: a "fading" technique and the elimination of inadvertent sensory reinforcement for "error" responses.

The basic questions which have guided the current experimental investigation are the following: (a) Is the mirror-image oblique line discrimination actually "impossible," or can the discrimination be effected under suitable conditions for learning? (b) Are certain critical variables, both stimulus and subject-history, influencing the presence or absence of this particular discrimination? (c) Using this difficult discrimination as a vehicle, can particular classes of variables be identified and then successfully manipulated to influence other kinds of discrimination learning in children and adults?

To answer the first question, an initial study was performed to examine the acquisition of the oblique-line discrimination under different presentation conditions. Stimuli were mirror-image lines

photographed on slides which were presented by rear-projection onto two round stimulus windows; these windows were "touch sensitive," and the subject responded directly by touching the window (i.e., directly to the stimulus locus). Experimental programming and data printouts were controlled by a PDP-7 on-line computer. The four conditions represented combinations of two independent variables: the nature of the stimuli themselves and the nature of their presentation. (1) In a "constant stimuli" condition, the two mirror-image oblique lines were presented on each of 50 trials; each stimulus was constant in terms of background brightness, line darkness, and degree of tilt. The other condition utilized a fading technique in which S+ (the correct stimulus) was gradually "faded in." This fading sequence consisted of three phases. In Phase 1, S- began as a completely darkened window and gradually became a window which matched the background brightness of S+, but no line was present. In Phase 2, a 135- (or 45-) degree oblique line was faded from no line at all to a line which matched S+ in darkness. Phase 3, which were criterion trials, consisted of 10 presentations of both constant stimuli (equal line darkness and background brightness). The fading sequence was utilized in an attempt to produce what has been referred to as errorless discrimination learning, and the hypothesis was that by fading in the S-, error responses would be essentially eliminated. (It should be noted, in relation to previous animal studies on errorless learning, that although pigeons characteristically have no tendency to peck at a darkened window, children have no such built-in specific negative response tendency--see Hilgard and Bower, 1966)

(2) The second independent variable manipulated in the initial study was a technique to eliminate inadvertent sensory reinforcement. One condition used is referred to as the "no-delay" condition: immediately upon the subject's response to either S+ or S-, both windows were darkened, and if the subject had responded to S+ he also received a marble. This condition is the one typically used in most studies of discrimination learning, and it proposes a theoretically interesting

problem. If, as some theorists (Kish, 1966) have argued, any immediate change in the stimulus situation contingent upon a response reinforces that response, then S- responses are being inadvertently reinforced by virtue of the fact that a response to either S+ or S- typically produces stimulus change (i.e., darkening of the window). In an effort to control for, or eliminate this inadvertent source of reinforcement, a "delay" condition was introduced in which: (a) an S+ response produced a marble, and both stimuli went off immediately, and (b) an S- response produced no stimulus change, no marble was presented, and both stimuli remained on for 5 seconds.

It was anticipated that differential learning in the four conditions (constant-no delay, constant-delay, fading-no delay, fading-delay) would give some hint of the relative importance of the two variables under study. The results were disappointing. Not one subject learned the discrimination. In the constant-stimuli condition, both delay and no-delay groups performed at chance throughout the entire 50 trials. In the fading conditions, both delay and no-delay groups performed very well during the first two phases of the fading sequence, but when presented with the 10 criterion trials (constant stimuli), their performance dropped to chance level. Latency data also were uninformative in that there were no differences among any of the groups.

Inspection of the records of the subjects in the two fading conditions showed that they started making many errors during Phase 2 of the fading sequence (where S- was being faded in from no line at all to a line equal in darkness to S+). This suggested that perhaps the fading sequence that had been used was not only inadequate, but also inappropriate. The critical feature which would seem to be the key to the discrimination is line <u>orientation</u>. However, by fading in background brightness and line darkness, the subject's attention had been directed to stimulus dimensions that were irrelevant to the solution of the discrimination. The subject's attention may have been under stimulus control, but irrelevant aspects of the stimulus were controlling it.

An attempt was made to remedy this situation by devising a new fading sequence which consisted of four phases: (a) fade in background brightness of S-; (b) fade in vertical line until the vertical line (S-) was of equal darkness to S+; (c) fade the angle of S- from a vertical line to a 135-degree line in 5-degree steps, and (d) 10 criterion trials in which S+ and S- were equal in every respect except for their orientation. The new fading sequence was used under both delay- and no-delay conditions. Again, not one subject in either condition learned the discrimination. Upon inspection of the individual protocols, it could be seen that subjects, though not performing errorlessly, performed very well until they were presented with the criterion trials, and then their performance immediately decreased to chance level.

A correction procedure was then incorporated into the procedure: using the modified fading procedure and a constant condition, control of the apparatus was reprogrammed so that a subject had to make a response to S+ on every trial in order to proceed to the next trial. This procedure was as unsuccessful as the preceding ones, and only 1 subject learned the discrimination. The point where subjects began to make many errors was the same as that without the correction procedure, i. e., at the beginning of the criterion trials.

Since these results were so discouraging, it was decided to take a completely fresh approach and to abandon temporarily the computer-controlled apparatus, the slides, and the "response-insensitive" testing procedure. The investigators were by now convinced that in order to teach a difficult orientation discrimination, efforts had to be concentrated on making sure that the aspect of the stimulus situation that controlled the subject's attention was, in fact, the orientation of the line, and nothing else. A series of small pilot studies (3 or 4 subjects in a group) was initiated in an attempt to bring the subject's attention under the control of line orientation *per se*. The lines were drawn on cards, and the subjects were tested by an experimenter, face to face, with the experimenter being very

sensitive to the nature of subject's responses, and varying the procedure to accommodate to the particular subject.

In order to immediately sensitize the subject to the fact that orientation was critical, a number of different pretraining procedures were tried out. Studies by Jeffrey (1966) and Over and Over (1967) indicated that having the subject label S+ and S- differentially, or having him point the way the line or arrow was going, had some facilitative effect on learning the discrimination. Thus, the first series of pretraining procedures consisted of a series of trials in which subjects were presented two mirror-image oblique lines, but at the top left and top right of each was a large arrowhead. The subjects were taught to choose, for instance, the arrow that pointed to the upper left corner of the card. Once they learned this, on successive trials, the size of the arrowheads was diminished until they disappeared. Subjects performed well until the arrows were completely absent, at which time they "broke down" and performed at no better than chance. Similar procedures were tried: with printed fingers (the subjects were required to point the way the finger was pointing, were told that one was correct, and that the direction would always be correct) and with different colored lines. All proved unsuccessful. Although the subjects could always tell which line was different (when presented two 45- and one 135-degree lines simultaneously), they could not reliably choose the correct line on each trial when the stimuli were presented simultaneously,

Only recently has a measure of success been attained. Following Jeffrey's (1966) procedure, a 4-phase pretraining procedure was tried: (a) using successively presented arrows, subjects were taught to reliably choose one of them; (b) using the same lines, without arrowheads, again, presented successively, subjects were taught to choose one reliably; (c) children were taught to label the two lines, presented successively; S+ was "right," S- was "wrong"; (d) criterion task lines were presented simultaneously and subjects were told to point to the "right" line every time. Jeffrey's results were partially

replicated in that 4 out of 10 subjects tested learned the discrimination. Currently, Jeffrey's procedure is being modified, and the attempt is being made to determine which, if any, of the steps used is unnecessary. If an optimal sequence and procedure for teaching this discrimination to a maximum number of subjects is found, this strategy can then be used to teach other difficult discriminations.

Some interesting things have been learned from this whole line of research. Perhaps the most interesting is the finding that for these particular stimuli, and quite possibly for all mirror-images, successive presentation is more facilitative in acquiring the discrimination than is simultaneous. This finding is contrary to the findings about discrimination learning in the psychological literature: Almost without exception, studies comparing the two modes of stimulus presentation have found simultaneous presentation to be easier. It would be premature to speculate on why this contradiction exists in the current line of study.

Another interesting finding, albeit it informal in nature and derived solely from observing our subjects in action, is that most success (in terms of the number of subjects learning the discrimination) has occurred when the training and criterion trials were very fast-paced, i.e., no more than 1 or 2 seconds apart. Theorists (e.g., Neisser, 1967) have suggested that when a stimulus is presented, the subject forms a mental image or icon of that stimulus; this short-term memory decays very quickly. Perhaps when two stimuli are very similar, this short-term storage is necessary for the young child, so that he can use it as a basis for comparing the present with the previously presented stimulus. Fast-paced trials should facilitate the comparison of stimuli, relative to slow-paced trials, since short-term memory has had less chance to decay. But again, this is premature speculation.

The third lesson learned from the research carried out so far, is that identification of the appropriate aspects of the stimulus situation is particularly critical if subjects are to be taught a different discrimination and that identification of these aspects and the process of bringing behavior under their control can be very elusive phenomena.

II. COMPUTER-ASSISTED LABORATORY IN STATISTICAL INFERENCE

(W. W. COOLEY)

Work on the computer-assisted laboratory in statistical inference is currently in the formative evaluation stage. It has been demonstrated that one hundred students per term can in fact use the Pitt Time-Sharing System on a weekly basis to do the laboratory work required for the first course in statistical inference. A current major concern is with the evaluation of the labs, in an attempt to determine their impact on student mastery of statistical concepts and on student attitudes toward the computer.

Concerning the latter, a thesis by Paul A. Stieman was completed (and will be issued as a technical report) in which the primary concern was how the students' concept of the computer changed as a result of this course. Employing a semantic differential technique, very definite shifts were found in student attitudes toward the computer. The group found the computer to be more "pleasant" after their exposure to it as a learning aid. Furthermore, the students seemed to find the computer to be more "necessary," and they tended to "like" the computer more after their eight-week exposure to it through the laboratory exercises. In general, direct exposure apparently enabled the students to develop an understanding of the capabilities and limitations of the computer; this understanding was reflected in the attitudinal changes observed.

The most useful outcome of Stieman's research was the demonstration that the data analysis labs (in which students applied statistical techniques to project TALENT data stored on disk) appear to be more instructive and tend to command greater interest than do Monte Carlo experiments. Of course, this is a difficult comparison to make because the Monte Carlo exercises are more theoretical and more difficult.

Stieman's research suggested several specific concerns which

are now being studied in a more controlled experiment. The forty students enrolled in the winter term were randomly assigned to two lab groups, one using the computer lab approach and the other doing most of the Monte Carlo studies with dice and other physical processes. The concern of this second doctoral study is that the computer laboratory experiences may be too abstract for the students to fully appreciate. The payoff here is more likely to be an assessment of each of the laboratories with respect to specific concepts as measured by clusters of items on the midterm and final exams rather than some gross overall evaluation of whether the computer labs are "worthwhile." That is, by having a control group, some of the trends observed by Stieman can be more specifically studied regarding the relative effectiveness of the different types of labs. The results of this work should be available within several months.

The work on the development of the statistical laboratory has attracted the attention of individuals interested in statistical computing. William W. Cooley was invited to prepare a paper for a Conference on Statistical Computation, University of Wisconsin Computing Center, April, 1969. The text of his remarks will be issued as a technical report.

III. THE DEVELOPMENT OF PEDAGOGICAL COMPUTER LANGUAGES FOR CAI.

A. REAL-TIME CONTROL LANGUAGES FOR CAI AND PSYCHOLOGICAL EXPERIMENTATION. (R. FITZHUGH)

During the past six months, two primary language development activities have been underway. (1) The SKOOLBOL-I programming language currently in use was significantly upgraded, and the SKOOLBOL-I compiler was implemented on LRDC's PDP-7/9. (2) Basic design work continued on a second-generation general-purpose programming language suitable for computer-assisted instruction work as well as laboratory psychological experimentation.

1. Evaluation of SKOOLBOL-I

A complete evaluation of the SKOOLBOL-I programming language and its effectiveness was undertaken. It was determined that although SKOOLBOL-I has been proven to be a valuable tool, the language has limitations which are difficult to overcome within its present structure. The language was originally designed to conform to the programming requirements of the LRDC Time-Sharing System (LRDC-TSS), particularly those relating to the generation of reentrant object code. In order to accommodate a wider range of CAI experimentation, extensive modifications were made to the LRDC-TSS during the past six months; these modifications have rendered many of the reentrant-code generation features of SKOOLBOL-I obsolete.

The input/output capabilities of SKOOLBOL-I were found to be inadequate for highly interactive CAI and for the data reduction required for rapid experimental analysis. The language was originally designed for a far simpler input/output structure than presently exists. Input/output devices added recently to the system such as disk, printer, magnetic tape, and card reader are not supported by SKOOLBOL-I.

A particular hardship is the SKOOLBOL-I requirement that all output data from CAI or psychological experimentation programs be directed to the paper tape punch rather than to faster, more flexible devices such as disk or magnetic tape. Also, the arithmetic and data-handling capabilities of SKOOLBOL-I are weak: Arithmetic statements are evaluated and executed from left to right only, and all variables are considered to be integers. Because parentheses cannot be used to alter the hierarchy of operations, complex arithmetic expressions cannot be evaluated. Also, because SKOOLBOL-I does not provide array capabilities, subscripted variables are not possible; all data variables to be manipulated must be named.

As a result of the language evaluation, a number of significant modifications were made so that the SKOOLBOL language might become a more useful tool until the second-generation language under development is operational. The reentrant-code generation features were revised to conform to the newer requirements of the LRDC-TSS. The input/output capabilities were expanded so that SKOOLBOL now supports all major system devices. The command repertoire of the language was consolidated, and redundant and obsolete commands were eliminated. The SKOOLBOL compiler itself which previously ran on the University's IBM 7090 was rewritten and implemented on LRDC's PDP-7/9 computer system.

In the future, no further modifications are contemplated, and the language will be stabilized to facilitate its use as an applications programming tool. The revised language will be released as SKOOLBOL-II, and a revised user's manual is under preparation.

2. Development of a Second-Generation Language.

Of greater significance is developmental work on a second-generation general-purpose programming language in which the emphasis is on generality and machine independence. Basic design work on the language has been underway for several months. With respect to primary design philosophy, the language has been structured to permit a phased

and upwardly compatible implementation: as soon as the key portions have been implemented, the language will be put into use even though developmental work is still underway. Later expanded versions of the language will offer additional features but will be capable of compiling programs written in earlier subset versions of the language. Particular emphasis will be placed on data-handling capabilities. Bit manipulative functions will be included to permit close control in laboratory or data acquisition environments, and character string variables will be permitted to facilitate text processing in computer-assisted instruction application.

The characteristics of a particular system (such as LRDC-TSS) or of idiosyncratic peripheral devices will not be structurally incorporated into the language. Rather, the input/output structure will be designed to support several classes of input/output devices each with a set of similar characteristics. An additional capability will be provided to enable a user to define within the language framework any wholly idiosyncratic device unique to a particular installation. In this fashion, a relative machine independence can be achieved which would permit the implementation of the language on a wide variety of real-time systems, particularly those used for computer-assisted instruction and laboratory psychological experimentation.

B. AUTOMATON ANALYSIS OF INSTRUCTIONAL STRATEGIES (RAMAGE)

The report entitled "A Mathematical Investigation of Three Attributes of Automated Instruction," is currently being revised. Three attributes of an automated instructional configuration were investigated by constructing a model of the configuration and studying the effects of the attributes upon the model. These attributes were: (a) an interactive arrangement between a user and an automated environment, (b) the separate though related control and data (user-oriented) programs, and (c) the simulation of instructional situations. The proposed model was a three tape automaton (Turing machine) which

allows user-generated symbols to be placed on one of its tapes during computations and a language structure providing the operational description and link between user and automaton. The three automaton tapes were defined as an output tape which provided a one-way information channel to the user, a data tape which was a computation tape and the opposite information channel to the user, and a control tape which was available only to the automaton as a computation tape.

The study of these attributes with the proposed model resulted in the description of a non-deterministic automaton utilizing a linear-bounded (context-sensitive) language to provide the user link and simulation sophistication. Linguistic models of languages and machines are analogous to types of instructional situations, and the approach initiated might provide the framework for a more rigorous classification of instructional strategies.

It has been a somewhat loose practice in the last few years to categorize automated instruction into four ranges of complexity labeled drill, tutorial, dialogue and responsive. In practice, the drill strategy is similar to a testing procedure where the user is presented sequences of problems which have a unique or limited set of correct answers. The program sequence may to a limited extent (small numbers of alternatives) depend upon the history (past performance) of the user. Tutorial sequences present limited amounts of presumedly new information to which the user is expected to respond in a limited manner that is indicative of his comprehension. The sequence of presentations may again in a limited manner depend upon the history of the user. Dialogue strategies are structured so that the user effectively determines the sequence of presentations by the inquiries (inputs) he imposes upon the system. These inquiries, though possibly large in number, are finite and limited to the topic of instruction. The responsive strategy is the most loosely controlled of the four strategies. The automated portion of the system essentially models an instructional situation (phenomenon or topic) and the user is allowed to explore or manipulate this model in an arbitrary and unpremeditated manner.

In order to relate these strategies to models, the distinguishing characteristics of the strategies need to be identified. All the strategies require at least the two basic attributes of on-line interaction and separated control and data, and they can be categorized in accord with their response limitations (user input constraints) and data (user history) sensitivity. Data sensitivity refers to the extent that past performance affects the generated sequence of presentations. The drill strategy normally has a very limited response (correct answer) and uses small amounts of history (last five responses as an example) in making decisions regarding the future sequence of presentations. The tutorial strategy is similar in that the responses are limited to a predefined correct set and limited amounts of history are used in program decisions. In many typical cases of tutorial strategy, only the immediate response is used as a decision parameter. The dialogue and responsive strategies are the most interesting in that both require access to unbounded amounts of history since the extent to which a user pursues a goal is arbitrary and his entire past performance is relevant to the programs. The responses (inquiries and statements) are limited for the dialogue, but are unbounded for the responsive strategy where, by definition, a user may explore and create program configurations or sequences that did not exist in the initial configuration. The concept of response as used in this latter strategy is extended to include the computational consequences of the response.

The system model comprising the user, automaton, and language is affected by the instructional strategy employed. The dialogue and responsive strategies both indicate the need for unbounded tapes (i.e., Turing machines) which is not a requirement for the particular attributes investigated. The linear-bounded model, in fact, implies finite tapes. This linear-bounded model as described obviously accommodates the drill and tutorial strategies, but the question arises as to the extent to which it could be degraded for special cases. For example, a drill or tutorial program that required only multiple choice answers could be accommodated on a finite state machine. The data are trivial

enough so that no significant interpretation is required. The role of the Push Down Stack automaton does not seem to have especially useful properties with respect to instructional strategies although it is the intermediary device between finite state and linear-bounded machines.

From the system model viewpoint discussed above it is then possible to categorize instructional strategies in a slightly different way as: (a) choice response, limited history, (b) limited response, limited history, and (c) unlimited. These strategies correlate with finite state, linear-bounded, and Turing machines respectively.

IV. ANNUAL CONFERENCE ON THE APPLICATION OF SCIENTIFIC DEVELOPMENTS TO INSTRUCTIONAL TECHNOLOGY

The proceedings of the 1967 conference were published in the book Approaches to Thought (Editor, James F. Voss; Charles E. Merrill Books, Inc., 1969). Proceedings of the 1968 conference are currently being typed for technical report dissemination. The latter volume will be entitled Perception of Thought, edited by James J. Jenkins and David Horton; the technical report proceedings will later be published as a memorial book to Paul M. Kjeldegaard, organizer and chairman of the conference.

The 1969 conference will be held June 10-11, 1969 on the topic "The Nature of Reinforcement." Participants and topics are outlined below:

Conference Chairman: Robert Glaser, University of Pittsburgh

REWARD IN HUMAN LEARNING: THEORETICAL ISSUES AND STRATEGIC CHOICE POINTS

William K. Estes, Rockefeller University

Discussant: James F. Voss, University of Pittsburgh

INCENTIVE TO LEARN: EXTRINSIC AND INTRINSIC REINFORCEMENT

Frank A. Logan, University of New Mexico

Discussant: Roger W. Black, University of South Carolina

HUMAN MEMORY AND THE CONCEPT OF REINFORCEMENT

Richard C. Atkinson and Thomas D. Wickens, Stanford University

Discussant: Lee W. Gregg, Carnegie-Mellon University

PUNISHMENT AND REINFORCEMENT

David Premack, University of California, Santa Barbara

Discussant: George Wischner, University of Pittsburgh

ELICITATION, REINFORCEMENT AND STIMULUS CONTROL

A. Charles Catania, New York University

Discussant: John W. Donahoe, University of Kentucky

PHYSIOLOGICAL AND NEUROCHEMICAL ASPECTS OF REINFORCEMENT

Larry Stein, Wyeth Institute

Discussant: Alan Fisher, University of Pittsburgh

VICARIOUS AND SELF-REINFORCEMENT PROCESSES

Albert Bandura, Stanford University

Discussant: Jacob L. Gewirtz, National Institute for Mental Health

REINFORCEMENT: APPLIED RESEARCH

Montrose M. Wolf and Todd R. Risley, University of Kansas

Discussant: Lauren B. Resnick, University of Pittsburgh

GENERAL DISCUSSION

John B. Carroll, Educational Testing Service

Robert M. Gagné, University of California

Robert M. W. Travers, Western Michigan University

Proceedings of the 1969 conference will be edited by the chairman, and will be issued as a technical report.

V. GENERAL PAPERS ON LEARNING AND INSTRUCTION.

"Concept Learning and Concept Teaching" by Robert Glaser was published as a chapter in Learning Research and School Subjects, edited by Robert M. Gagné and William J. Gephart (F. E. Peacock Publishers, Itasca, Illinois, 1968, pp. 1-38). "Learning" by Robert Glaser was recently published in the Fourth Edition of the Encyclopedia of Educational Research (Macmillan, 1969).

A paper entitled "Psychological Questions in the Development of Computer-Assisted Instruction" was presented by Robert Glaser at a Conference on Computer-Assisted Instruction, Testing, and Guidance at the University of Texas in October, 1968. The paper, which is scheduled for publication in a volume published by Harper and Row, will be issued as a technical report.

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